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Mandibular Osteodistraction for Correction of Deep Bite Class II Malocclusion in a Horse

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Objective—To describe a technique for, and outcome after, mandibular osteodistraction in the horse.
Study Design—Clinical report.
Animals—Warmblood horse.
Methods—A half ring external fixator was applied on both sides of an osteotomy site performed on the mandible of a colt. A bite plate was placed on the upper incisors creating occlusion between lower and upper jaw. After a 5-day latency period, distraction was applied (1 mm/day) until the overjet was judged normal.
Results—Mandibular elongation and correction of brachygnathia was obtained without major complications. Six months after the procedure the overjet reduction was considered stable.
Conclusions—Mandibular osteodistraction can be considered for treatment of severe brachygnathia in yearlings.
Clinical Relevance—Distraction osteogenesis has the advantage of progressive elongation of the mandible, allowing concurrent bone remodeling and soft tissue adaptation. Severe mandibular incisor malocclusion in horses outside the maximal growth phase can be corrected using this technique.

INTRODUCTION

INFERIOR OR mandibular brachygnathia is probably the most common congenital dental defect encountered in foals.[1] It is defined as an abnormal shortening of the mandible compared with the maxilla and leads to an increased overjet and nonocclusion of the incisor teeth. Overjet is defined as the horizontal projection of maxillary incisors beyond the mandibular incisors, usually measured parallel to the occlusal plane whereas overbite is the vertical projection of the maxillary incisors over the mandibular incisors[2] (Fig 1). Although commonly considered an inherited disorder with some familial tendency in Thoroughbred horses,[3] conclusive evidence for an hereditary basis has only been substantiated in cattle.[4,5] Thus, ethical considerations rise when considering treating this disorder, and mild aesthetic cases should probably remain untreated. However, profound malocclusion and marked rostral and ventral projection of the maxillary incisors (parrot mouth) or class II malocclusion[6] can become quite debilitating and treatment should be considered.[3] With aging, dental malocclusion can impair ability to prehend food and lead to chronic dental problems, malnutrition, and growth retardation.[7]

Moreover, evidence obtained from recent studies in rats and reports in humans demonstrate the relationship between dental malocclusion, masticatory dysfunction, and alignment of the spinal column.[8–12] Scoliotic curves developed in young rats with induced dental malocclusion and resolved once occlusal balance was reestablished.[9]

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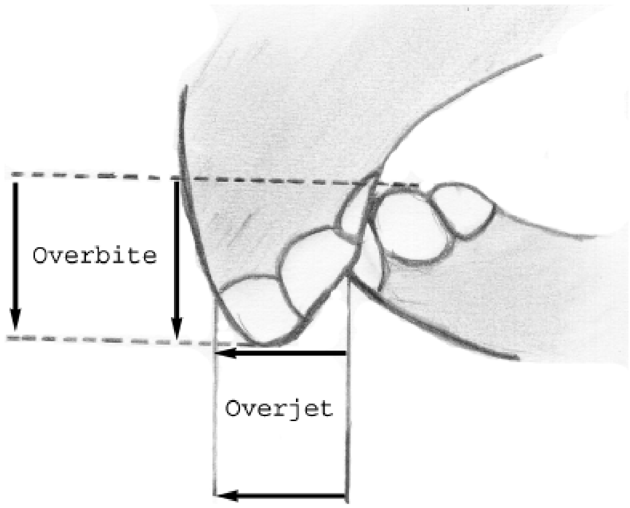

Fig 1. Illustration of overbite/overjet. Overjet is defined as the horizontal projection of maxillary incisors beyond the mandibular incisors, usually measured parallel to the occlusal plane. Overbite is defined as the vertical projection of the maxillary incisors over the mandibular ones.

Class II (sagittal overbite or overjet) and class III (underbites or negative overjet) are the most common congenital malocclusion patterns found in humans and have been associated with cervical lordosis and anteriorly displaced posture, and cervical kyphosis and posteriorly displaced posture, respectively.[10,12] These reports underscore the importance of correct dental occlusion in vertebrates.

Spontaneous correction of mild class II malocclusions in horses can be achieved by the use of a biteplate.[3,13] More severe cases can be surgically corrected using tension band techniques with or without use of an acrylic biteplate.[14–16] Using this technique, the tension applied to the maxilla will slightly retard growth allowing the mandible to "catch up" with the maxilla. Both techniques provide reasonably good results and correction up to 2.5 cm has been obtained in skeletally immature animals.[15,16] In older animals, where benefit of natural growth cannot be obtained, other surgical corrective options should be considered.

Osteodistraction as a corrective technique for mandibular shortness in humans was first described in dogs by Snyder in 1973.[17] Currently, the technique is commonly used for correction of facial deformities in children and adults.[18–21] Mandibular osteodistraction has been studied experimentally in several species,[22–27] but we were only able to identify one clinical report where it was used in a large sized camelid.[28] Thus, we report our experience with a mandibular osteodistraction technique in a 1-year-old Warmblood colt with a severe class II malocclusion.

CLINICAL REPORT

A 1-year-old male Belgian Sport Horse, weighing 391 kg, was admitted for evaluation of parrot mouth. The malocclusion was detected at birth, but the owners had been informed that correction was not possible. Because the malocclusion worsened, the owners sought a second opinion.

This foal was the 6th progeny of this mare. None of her other foals, including the 2007 foal, nor any of the progeny of 3 generations of mares from which she originates had malocclusion. The full progeny of the sire is unknown; however, the owner reported having had several other foals from this sire and 2 other foals sired by him in 2005 have slight overjet.

The malocclusion was clearly noticeable without opening the mouth and at oral examination an overbite of ~2 cm and an overjet of ~3.5 cm was evident (Fig 2). This malocclusion was more severe than observed on radiographs from 2 months earlier, where the overbite was ~1.5 cm and the overjet, 3 cm. Lateromedial, dorsoventral, and left and right oblique radiographic projections taken on admission revealed a markedly shortened and dorsally curved rostral part of the mandible (Fig 3). The premaxilla had strong ventral incurvation (proclination). No obvious malocclusion of the cheek teeth was present. The colt had some difficulty in eating.

Clinical and preanesthetic examination of the colt revealed no abnormalities. With owner consent, mandibular osteodistraction was attempted to correct the defect.

Surgical Procedure

Measurements of the colt's mandible were taken before surgery and an adapted external fixator frame was constructed using the Imex™ circular external skeletal fixator System (IMEX, Instrulife, Oostkamp, Belgium).

Fig 2. Preoperative photograph of the colt's mouth showing the overbite and overjet.

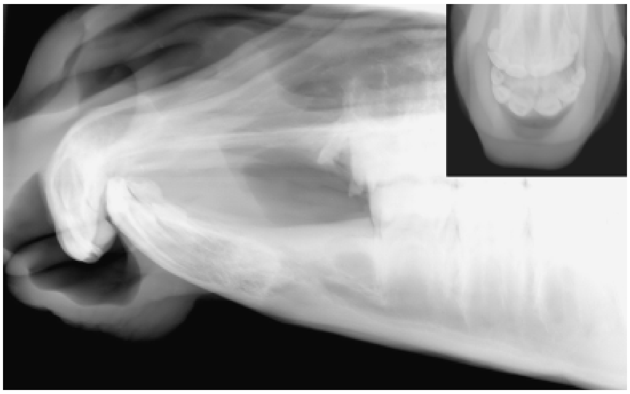

Fig 3. Laterolateral and dorsoventral (upper right) radiograph before surgery, showing the overbite and overjet and the external deformation of the soft tissues.

The frame initially consisted of 2 separated units of three, 118 mm × 6.3 mm one-third ring arches. The individual ring arches in each unit were interconnected by means of 4 rods (Fig 4) and these units were further connected by four 255 mm × 6 mm threaded connecting rods (thread pitch, 1 mm), later used as distraction rods. Small spacers were placed between the arches and the nuts at the distraction rods to allow access to the nuts with a wrench. The fixator was fully constructed and autoclaved before surgery. The colt was fed sloppy mash (including extruded grains, distended grass nuts) for 1 week before surgery in preparation for major diet changes after surgery.

Flunixin meglumine (1.1 mg/kg intravenously [IV] once daily), vitamin E/Se (Myogaster®, 100 mg/kg intramuscularly [IM]; VMD, Arendonk, Belgium) and penicillin G sodium (20,000 U/kg IV) were administered preoperatively. Acepromazine (0.1 mg/kg IM) was administered 1 hour before induction of general anesthesia with xylazine (0.6 mg/kg IV), ketamine (2.2 mg/kg IV), and midazolam (0.06 mg/kg IV). After orotracheal intubation, the colt was positioned in dorsal recumbency and anesthesia was maintained with isoflurane in oxygen, using a closed system with a semicontrolled ventilator. The ventral and ventrolateral aspects of the entire mandible were aseptically prepared and draped.

The fully constructed fixator was positioned on the ventral aspect of the mandible and correct position was determined visually. The most rostral ring of the caudal unit was positioned at the level of the second premolars (Triadan 706/806). During surgery, we removed the most rostral ring of the rostral unit so that there were only 2 arches in the rostral component. The fixator was attached to the mandible by 10 no point standard threaded 9/64″ half-pins (INTERFACE™, IMEX, Instrulife; Fig 5). Localization of the pin insertion sites was made using fluoroscopic guidance to avoid damage to the dental alveoli. After skin stab incisions, holes were predrilled using a 3.5 mm drill bit, and pins were inserted. The threaded rods (distraction rods) were then removed to allow access to the mandible for osteotomy. An 8 cm ventral to ventrolateral skin incision was made bilaterally over the mandibular rami. The mandibular bone was exposed by blunt dissection and the periosteum sharply incised and elevated. Osteotomy of both rami was made with an oscillating saw ~1 cm rostral to 706/806. Saline (0.9% NaCl) solution was used for cooling during sawing.

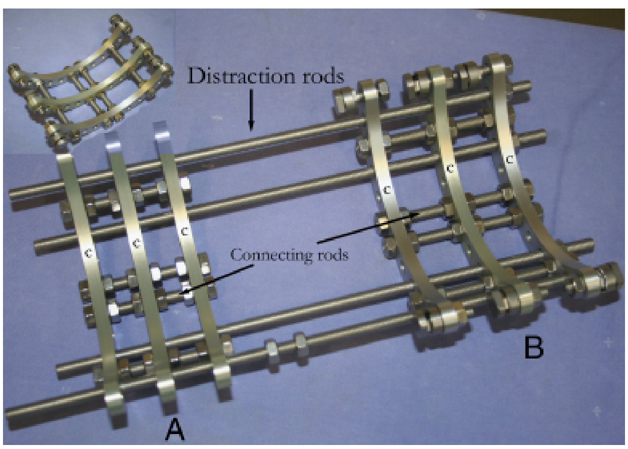

Fig 4. The fixator was composed of a rostral (A) and a caudal (B) unit (individual unit shown in upper left corner), both containing 3 arches (C). Each of the 3 arches is interconnected with 4 threaded rods (connecting rods). Both units are united with 4 threaded rods used as distraction rods. During surgery the most rostral arch was removed.

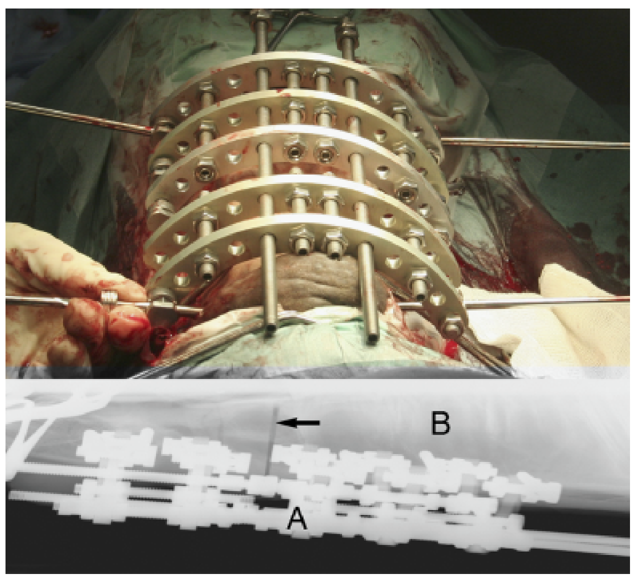

Fig 5. Intraoperative photograph and radiograph showing placement of the fixator (A), mandibular ramus (B); arrow indicates osteotomy site.

Fig 6. Horse with fixator after surgery. Right corner seen from dorsal, below seen from lateral.

The subcutaneous tissues and skin were closed in layers, and a cotton bandage was applied around the structure.

The threaded rods were repositioned and small spacer placed on the rods on each side of the arches before placing the nuts. Postoperative radiographs were satisfactory, showing pins in the ventral mandible, avoiding the roots of cheek teeth. Before surgery, an 8-cm-long aluminum plate was shaped according to the curve of the upper incisors and small holes were drilled into it. This biteplate was applied at the end of surgery on the upper incisors using small diameter cerclage wire and acrylic paste (Vertex Self Curing®, Vertex-Dental NV, Zeist, the Netherlands). Procedure time was 3.5 hours and recovery from anesthesia was uneventful (Fig 6).

Postoperative Care

Ceftiofur (2.2 mg/kg IM once daily) and phenylbutazone (2.2 mg/kg IV once daily) was administered for 10 days. Some swelling developed around the mandible by 24 hours but the colt remained comfortable. The bandage was changed daily and the fixator and pins were cleaned using a povidine iodine solution and a brush. Nitrofural (0.2%) ointment (Furacine® Soluble Dressing, Limacom NV, Zonhoven, Belgium) was applied at the pin exit points before each new bandage. Different bandaging techniques were tried but a piece of Gamgee tissue folded over the sides of the fixator and partly pushed through the extremities of the pins and held in place with an elastic bandage applied in a figure of 8 over the edges of the fixator seems to work best. The colt was fed sloppy mashes with extruded grains and distended grass nuts without developing digestive problems.

On day 6, distraction (1 mm) was started and repeated daily, typically at the same time, by loosening the caudal nuts and tightening the rostral nuts of the caudal set of arches by 1 complete revolution. Two days after starting distraction, the colt showed signs of pain and discomfort, which were relieved by administration of morphine (0.1 mg/kg IM every 8 hours). One week after surgery, a draining tract developed at some skin sutures on the osteotomy site but this resolved quickly. Distraction was performed daily for 32 days. Distraction caused the skin to fold against the side of the pin away from the osteotomy and to create a skin defect on the osteotomy side of the pin; this defect only closed after distraction was terminated.

Examination of radiographs taken weekly showed presence of a progressively forming callus and gradual correction of the overbite and overjet (Fig 7). Because radiographic evolution of distraction seemed quicker than the improvement in dorsal curvature of the premaxilla, we decided at day 32 to only apply additional distraction every other day to permit the maxilla to curve back dorsally. Distraction was discontinued 42 days after initiation and a consolidation period of 8 weeks was allowed. Proclination of the upper incisors gradually self-corrected. The central and middle deciduous incisors (Triadan 701, 801, 802, 803) loosened progressively by forces induced on the biteplate and were lost 6 weeks after surgery. On intraoral radiographs, the dental buds of permanent incisors 301 and 401's were observed without evidence of damage. On palpation the colt seemed to

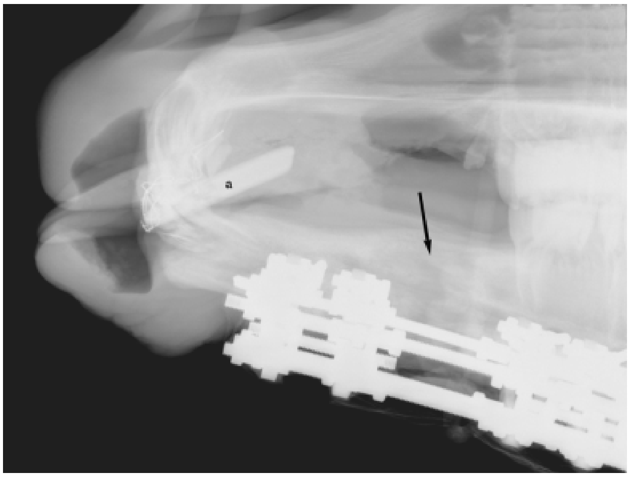

Fig 7. Radiographs (10 weeks after surgery) showing distraction gap (arrow). The radiodense structure between the incisors is the biteplate (A).

have lost deep sensitivity in the lower lip and was regularly seen with his tongue protruding to the left; however, the tongue was not hypoesthetic and normal, voluntary movement and retraction was observed.

The biteplate was removed after distraction was stopped and apposition of incisors was achieved. The colt's skull had progressively grown in the fixator and the most caudal arch of the appliance had penetrated the skin causing some discharge. Nine weeks after surgery, radiographic signs of pin loosening and bone infection were evident and the colt became febrile (39.6°C). Examination of the respiratory tract (endoscopy and tracheal lavage) revealed concurrent bacterial pulmonary infection that likely explained the fever. Ceftiofur (2.2 mg/kg IM once daily) was administrated for another 12 days based on microbial susceptibility testing of the tracheal lavage specimen. Rectal temperature remained slightly elevated ($\leq$ 39°C) and at 10 weeks after surgery, some discharge occurred at the level of the most caudal pins; microbial culture yielded *Staphylococcus aureus* resistant to ceftiofur but sensitive to fluoroquinolone so marbofloxacin (2.2 mg/kg IV once daily) was administrated in addition to ceftiofur. Rectal temperature decreased but drainage persisted; hence, 1 week later the most caudal arch was removed and the discharge resolved quickly. Rectal temperature remained slightly elevated until all pins were removed.

Callus formation progressed satisfactorily; however, the ventral aspect of the osteotomy site seemed less ossified, especially on the left side. Radiolucent zones around the pins increased in size and signs of bone infection began to develop. At the beginning of the 6th week of consolidation, the fixator was loosened and compression was applied to the osteotomy site. With evidence of progressive pin loosening, the fixator and pins were removed 13 weeks after surgery (7 weeks after distraction stopped and 1 week earlier than planned) with the horse standing and sedated (romifidine, 60 μg/kg; butorphanol, 0.01 mg/kg IV). A bandage attached to the head collar was used for 1 week to protect the pin tracts during healing. Hay and normal grass nuts were gradually introduced into the diet.

Stability of the fixator was good and no bending of the rods occurred during the treatment period. Because of the loosened and laterally bent incisors, accurate evaluation of the apposition of the mandibular and maxillary incisors was difficult. Slight overcorrection in length was obtained initially. At hospital discharge, a hard bony swelling was present on the left mandible at the site of osteotomy. The colt's body condition remained satisfactory and growth and development continued throughout treatment.

Outcome

The colt was evaluated 3 and 6 months after fixator removal. The hard swelling on the left mandible was markedly reduced in size at 3 months and barely detected by palpation at 6 months. Radiographically, pin holes remained at 3 months but had resolved by 6 months (Fig 8). The owner reported seeing the colt with left protrusion of the tongue for a few weeks after discharge. Tongue control and sensitivity of the lower lip were seemingly normal at 3 months. Almost complete correction of the overjet was obtained (Fig 8) by 9 months; however, some proclination of the premaxilla remained.

DISCUSSION

Distraction osteogenesis or callostasis is a technique commonly used to correct skeletal deformities. Application of gradual traction promotes regeneration and progressive growth of bone and soft tissues at a rate that is well tolerated by these tissues,[29,30] resulting in minimal surgical trauma. This has proven to be an effective technique in correction of class II malocclusions in man,[31] pigs,[32,33] smaller animals,[17,25] a camelid,[28] and in this colt.

We have successfully used growth retardation methods, with or without an acrylic biteplate, in horses and were initially considering these approaches for this colt. However, optimal results with growth retardation techniques occur when initiated around 3–4 months of age[15] with achievable correction of $\sim$5 mm every 3–6 months[7]; hence, the age of this colt and the severity of the malocclusion argued against its use. A combination of both techniques, tension band on the maxilla and osteodistraction, seemed unlikely to yield a good outcome because in our experience, tension band wiring tends to

Fig 8. Photograph and radiographic view (slightly oblique laterolateral view) at 6 months.

accentuate downward migration of the maxillary incisors and premaxilla instead of correcting it. A single-stage mandibular advancement with rigid fixation[34] or a slot osteosynthesis technique[35,36] as reported in humans could have been used, but both techniques are more invasive and did not seem to offer advantages compared with distraction osteogenesis. Moreover, distraction osteogenesis reportedly results in more rapid correction[37] of type II malocclusions in man compared with other techniques.

We achieved good cosmetic outcome by the end of the distraction period. Whereas the value of this outcome might be debated in equine practice, it does reflect a similar experience to human medicine where facial esthetics are important.[38]

Structural stability is of critical importance in fracture healing and for distraction protocols.[30] Unstable devices used for distraction yield poorly differentiated connective tissues, whereas good stability increases osteogenic activity in the distraction gap.[29] Concern was expressed about the lack of structural strength of the fixator used for mandibular lengthening in a camelid[28]; however, we used the same fixator type (Figs 4 and 6) originally developed for use on the appendicular skeleton of animals weighing <150 kg. Structural adaptations we used likely improved stability and strength. More threaded connecting rods were placed between the separate arches to yield stronger half-ring units. Secondly, 4 instead of 2 distraction rods, positioned at 3 and 9 o'clock holes, were used to join the 2 half-ring units. It should be noted however that nuts could not be turned adequately after this adaptation, because a 10 mm wrench would not fit in between 2 side-to-side nuts on the arch. Small spacers placed between the arches and the nuts on the distraction rods resolved this problem.

Distraction osteogenesis is governed by the principles of tension-stress described by Illizarov.[29] Tissues subjected to gradual, slow, and steady traction become metabolically active, stimulating both proliferative and biosynthetic cellular functions and combining controlled osseous healing with remodeling of both bone and soft tissues. Since the first descriptions of the distraction osteogenesis technique by Codivilla,[39] several studies, mainly by Ilizarov, have investigated the ideal latency time (time between osteotomy and initiation of the distraction), distraction rate (mm/day of bone stretching), rhythm (number of distractions/day), and consolidation period (neutral fixation) when using distraction osteogenesis. Considering little use of this technique has been reported in equine medicine and general characterization of osteogenesis has mainly been described for limb lengthening, optimal latency time, rates, rhythms, and consolidation period for this specific use in the equine mandible are unknown.

In a report on correction of deviated premaxilla in a horse using distraction osteogenesis, the authors suggest that the latency period of 7 days was probably too long.[40] This interval had been selected based on recommended latency periods (5–7 days) in humans for long bone lengthening. In veterinary patients and in several research reports, latency periods have ranged from 0 to 21 days,[30] but few reports refer to mandibular distraction. In mandibular distraction in sheep, changes in latency period do not alter mechanical properties of the new formed bone and it is suggested that a latency period may not be necessary for mandibular distraction.[41] However, these findings were not corroborated by similar studies in rabbits,[42] where longer latency periods resulted in higher tension in the distraction gap together with more mineralization. White and Kenwright[43] made general recommendations on latency periods for osteogenesis distraction techniques. The ideal latency period should be determined by the surgeon based on the type of bone, patient age, site and type of osteotomy, and degree of soft tissue damage. This is of importance to allow organization of a vascular network and healing of surrounding tissues at the gap before starting distraction. Given the paucity of information for mandibular distraction in large animals, we used a 5-day interval based on 2 experimental protocols used in large pigs.[32,33] Use of a longer interval may have permitted the osteogenic process to counter the distractive forces, preventing elongation.[29]

Distraction rates range can occur safely from 0.5 to 2 mm/day.[30] Clinical experience in humans and results from experimental studies in dogs[30,44] support use of a distraction rate of 1 mm/day. Faster rates delay bridging of the distraction gap and premature consolidation occurs if the rate is too slow. We selected 1 mm/day applied in a single session per day (rhythm and rate being the same), whereas in humans the recommended rhythm is 0.25 mm/session and 4 sessions/day. Such an approach in veterinary patients would be time consuming, difficult to apply, and costly because of added bandage changes. In chickens even higher distraction rhythms (120 steps/day versus 2 steps/day) have resulted in improved osteogenesis.[45] Successful use of this type of quasi-continuous distraction has been reported by others[30,32] and can be achieved using motorized or hydraulic[33] distraction devices. Adaptation of similar devices for use in horses would allow continuous distraction with less manipulation and care of the surgical site. Compared with intermittent distraction this approach has the advantage of not creating new microtrauma to the soft tissues at the distraction zone every time the distraction device is activated and may result in less pain.[32]

In animals, and specifically in horses, it is very difficult to keep the fixator clean, even more so on the mandible where efficient bandaging is challenging. Development of draining tracts and pin loosening was not surprising and could possibly be minimized if overall treatment time was reduced. Reduced distraction time would be difficult to achieve because of the overjet length that needs correction and although latency period could be decreased, reduced consolidation time by use of techniques that promote callus consolidation, i.e. mineralization would likely be a more effective strategy. Bone remodeling is driven by the principle of minimal effective strain, where adaptive architectural bone modeling is induced by strains equal or above a threshold value,[46] a principle confirmed in long bone fractures, where axial load compression of fracture segments through active weight bearing increases callus formation and shortens fracture healing times.[47–49] Recognizing that craniofacial and axial skeletal bones are not the same, studies in rabbits[50] and rats[51] have used sequential compression and distraction to determine if this principle could be applied to the mandible to shorten the consolidation period. Mofid et al[50] used daily alternating compression and distraction of 1 mm during the early consolidation period whereas Kim et al[51] successively applied distraction followed by compression during the consolidation period. Both approaches resulted in increased bone matrix synthesis with higher mineral apposition, suggesting this approach provides denser and more mature regenerate bone than conventional distraction techniques,[51] permitting shorter total treatment time.

Structural components of skin show increased activation during distraction[29]; yet skin wounds at the pin holes had delayed healing until the consolidation period when sufficient granulation tissue formed. These wounds healed quickly once the pins were removed.

Considering bone hardness and difficulty of medial access to the mandibular arch for corticotomy we used a classic osteotomy with an oscillating saw as reported for correction of nasal deviation in horses.[40] Although osteotomy does not adversely affect distraction osteogenesis outcome,[52,53] the quality of the bone regenerate and rapidity of consolidation in limb lengthening has been related to the degree of preservation of bone marrow, blood supply,[29,54] and periosteum (probably the most important factor),[30,55] a finding confirmed in mandibular distraction in goats when corticotomy and osteotomy techniques were compared.[56] Because oscillating saw osteotomy potentially creates thermal necrosis, corticotomy techniques with minimal bone marrow damage, preservation of the blood supply, and periosteum should be developed for the equine mandible. Complete circumferential mandibular corticotomy must be performed to avoid bowing of the mandible lingually when the lingual cortex is left intact.[31]

Corticotomy may also reduce trauma to the mandibular nerve, as likely occurred in our colt. Nevertheless, even without direct nerve trauma, loss of sensibility is a common problem encountered in humans[31] and dogs[57] with distraction osteogenesis. In monkeys,[58] nerve reactions to the tension produced by mandible lengthening were observed even without direct surgical trauma; however, 12 weeks after consolidation nerve function was restored. We also observed full return of lower lip sensation by 3 months.

Use of a biteplate was necessary in this colt to correct and/or diminish evolution of the overbite by transmission of forces from the mandible on the maxilla and because overbite prevented rostral advancement of the mandible. However, there were complications associated with use of a biteplate. To overcome the loss of cheek teeth occlusion needed for mastication, we fed the colt sloppy mashes instead of hay, starting 1 week before surgery and throughout treatment. By biting on the biteplate the colt lost several mandibular incisors. Loss of deep sensation of the rostral mandible may have played a causative role in this complication. Soft tissue lesions occurred underneath the biteplate, but healed quickly and without complications after removal.

Initially, we planned a consolidation period with neutral fixation of ~8 weeks.[28,59] Because of discharge from the caudal pin sites, pyrexia, and radiographic signs of bone resorption around the pinholes, we removed the fixator earlier despite radiographic evidence of incomplete mineralization at the distraction gap. In humans, ultrasonographic evaluation of callus after distraction is more sensitive then radiographic assessment.[60] We considered this approach but the fixator prevented access of an ultrasound probe to the distraction gap. Considering that only the ventral third of the osteotomy site (compressive side of the horizontal ramus) had lack of mineralization and that removal of the fixator would increase compression in this region we were confident that gap mineralization would occur quickly, as was subsequently evident by formation of hard bony callus mainly on the left mandible where the ventral gap was the largest.

Based on our experience with this colt and reports in other species, distraction osteogenesis should be considered for treatment of horses with type II malocclusion. Some technique adaptations and improved knowledge of ideal distraction kinetics would optimize this corrective technique.

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